

AD-A088 049 NAVAL RESEARCH LAB WASHINGTON DC
A DIVERTED PLASMA REVERSED FIELD PINCH. (U)
JUL 80 W M MANHEIMER
UNCLASSIFIED NRL-MR-4258

NAVAL RESEARCH LAB WASHINGTON DC
A DIVERTED PLASMA REVERSED FIELD PINCH. (U)
JUL 80 W M MANHEIMER
NRL-NR-4258

F/6 20/9

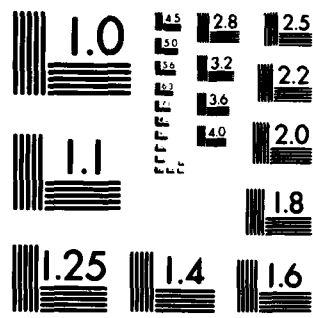
DOE-EX-76-A-34-1006

M

UNCLASSIFIED

END
DATE
FILMED
9-80
DTIC

$$\frac{2C}{\ln \ln n}.$$



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A088049

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4258 ✓	2. GOVT ACCESSION NO. AD-A088049	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A DIVERTED PLASMA REVERSED FIELD PINCH		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem.
7. AUTHOR(s) Wallace M. Manheimer		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375 (14) NRL-MR-4258		8. CONTRACT OR GRANT NUMBER(s) (11) 16 Jul 80
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Energy Washington, D.C. 20545 (12)		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 67-0896-0-0
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE July 16, 1980
		13. NUMBER OF PAGES 11
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) B		
18. SUPPLEMENTARY NOTES This work was supported by the Department of Energy under Contract EX-76-A-34-1006 (15) DOE-		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Reversed field pinch Divertor Minimum energy state		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This memo proposes a poloidal divertor as a method of reducing the strong plasma-wall interaction inherent in a reversed field pinch.		

DTIC
ELECTE
AUG 20 1980
S D

DD FORM 1473 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

252950

✓

CONTENTS

A Diverted Plasma Reversed Field Pinch-----	1
References-----	5

ACCESSION for		
NTIS	White Section	<input checked="" type="checkbox"/>
DDC	Buff Section	<input type="checkbox"/>
UNANNOUNCED		<input type="checkbox"/>
JUSTIFICATION _____		
BY _____		
DISTRIBUTION/AVAILABILITY CODES		
Dist.	AVAIL.	and/or SPECIAL
A		

A DIVERTED PLASMA REVERSED FIELD PINCH

This memo proposes the idea of using a poloidal divertor on a reverse field pinch, and is motivated by several recent experimental and theoretical works in this area. It has been shown that the natural, lowest energy state for a pinch to relax to is characterized by the force free state¹

$$\nabla \times \underline{B} = \mu \underline{B}. \quad (1)$$

For a cylindrically symmetric plasma, bounded by a perfect conductor of radius a , the solution is

$$\begin{aligned} B_z &= B_0 J_0(\mu r) \\ B_\theta &= B_0 J_1(\mu r). \end{aligned} \quad (2)$$

The quantities B_0 and μ are determined by the axial flux, $\int \int d^2r B_z(r)$, and the helicity $\int \int \int d^3r \underline{B} \cdot \underline{A}$, which is equal to the stored Volt seconds times axial flux.

Clearly, for $\mu a > 2.54$, the first zero of J_0 , or equivalently, $2I/aB_0c$ the pinch parameter greater than 1.27, the axial field reverses between the center and conducting wall. This field reversal has been observed on both Zeta² and $\eta\beta II$ ³. In fact in $\eta\beta II$ stable operation was feasible only while this toroidal field reversal persisted. Because of magnetic diffusion, the reversal point gradually moves outward. Once the axial field null reaches the wall, $\eta\beta II$ was observed to disrupt. Thus a reversed field configuration is not only the lowest energy state according to Taylor's theory, but this field reversal is apparently required for operation of such a device.

Manuscript submitted May 21, 1980.

Of course in the field reversed state strong axial and azimuthal currents exist right up to the plasma wall. Thus strong Ohmic heating of the plasma results here and the plasma struggles to achieve a high temperature right near the wall. Hence a strong wall-plasma interaction seems to be in the nature of a minimum energy state of a reversed field pinch. This is in sharp contrast to a tokamak, where the plasma current channels into the center of the discharge, away from the walls.

This strong wall plasma interaction in a reversed field pinch will, among other things, cool down the edge plasma, so this edge plasma is characterized by both strong heating and strong cooling. However the cooler the edge plasma, the shorter the resistive diffusion time in this region, and the more rapidly the field null is lost. Several schemes have been proposed to overcome this problem. In one,⁴ negative toroidal flux is fed through a toroidal slit in the conducting chamber (that is a voltage is imposed across this slit). However the input energy flux through this slit, $\frac{cE_{\theta}B}{4\pi}$ is dissipated in the cool outer region near the field null, and does not really go to heating the plasma. This additional power input to maintain the field null not only decreases the energy confinement time, but it also increases the plasma wall interaction since more power is deposited in the outer region of the plasma.

Another scheme to circumvent this problem, proposed by Ohkawa,⁵ is to impose the negative toroidal field in the outer region by using helical windings as in a stellarator. Then the plasma sets up the central current, but the field reversal is imposed externally and therefore cannot diffuse away. In addition a separatrix is imposed

by the helical perturbation so that the plasma has a natural boundary away from the wall. There are two potential problems with this scheme. First of all it is not clear how the plasma reacts to the helical windings. For instance if Eq. (1) is valid for the helically perturbed state, the plasma itself might try to set up strong currents in the region of the helical fields, but inside the separatrix. Another potential problem is that helically perturbed fields in toroidal geometry has no symmetry so the classical transport may be significantly enhanced, and flux surfaces can be more easily destroyed.

This memo then proposes an alternate scheme, which is simply to use a poloidal divertor inside the conducting shell. This might be simpler than setting up a separatrix with helical fields and also it does not destroy the toroidal symmetry. The divertor could be set up by simply imposing a vertical field so that flux surfaces in the poloidal plane are as shown in Fig. 1. It may be that the vacuum chamber would have to be re-designed so as to have a place for the diverted flux near the separatrix lines to go, above and below the plasma as is also indicated in Fig. 1. However if this could be done, the separatrix would serve as a vacuum boundary so that Eq. (1) would only apply inside this separatrix and there would be vacuum fields outside. Thus if the separatrix radius is denoted r_s , the toroidal and poloidal field might be as shown in Fig. (2).

It is not apparent what the density and temperature would be on the separatrix. However some information can be gleaned from reversed field theta pinch experiments.⁶ There it has been shown that the

temperature is nearly uniform out to the separatrix and the density decays to perhaps 25% of its maximum value. Apparently there are large surface currents near the separatrix which partially confine the plasma. In any case, the reversed field theta pinch plasma does seem to be isolated, by the divertor, from the radial wall.

To summarize, this memo proposes that reversed field pinches could be run with a magnetic divertor. This divertor would allow the Taylor minimum energy state to exist right up to the plasma edge, but could substantially reduce the plasma wall interactions inherent in a state with high current density right at the plasma edge. The divertor could be set up with the vertical field coils which usually exist in toroidal configurations.

This work was supported by the U.S. Department of Energy.

References

1. J. B. Taylor, Phys. Rev. Lett. 33, 1139 (1974).
2. D. C. Robinson and R. E. King, Proc. 3rd Int. Conf. Plasma Physics and Controlled Nuclear Fusion, Novosibirsk, USSR 1968 IAEA Vienna, Austria 1969.
3. A. Buffa et al., Workshop on Reversed Field Pinches, Los Alamos, N.M. April 1980.
4. J. Christainsen and K. V. Roberts, *ibid.*
5. T. Ohkawa, Phys. Rev. Lett. to be published.
6. R. Linford, Bull. Am. Phys. Soc. 24, 1082 (1979).

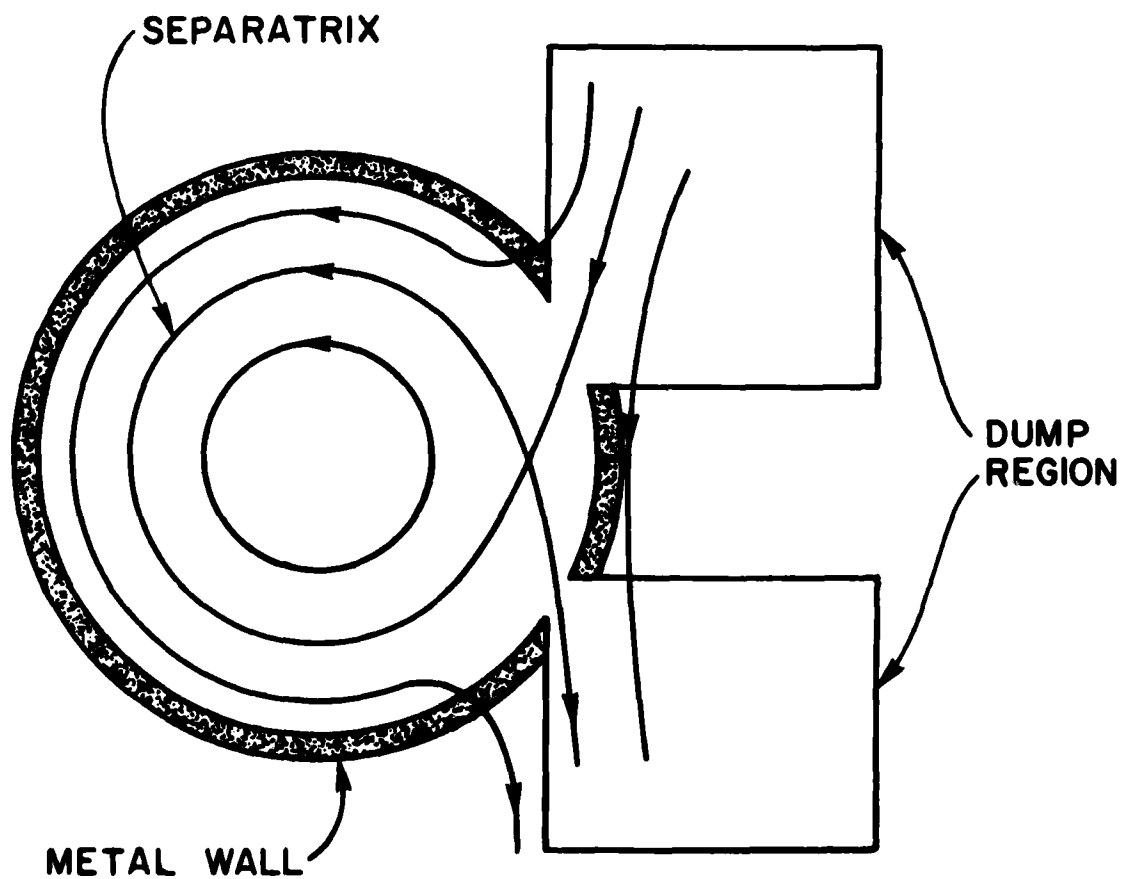


Fig. 1 - Schematic of a reversed field pinch plasma with a divertor

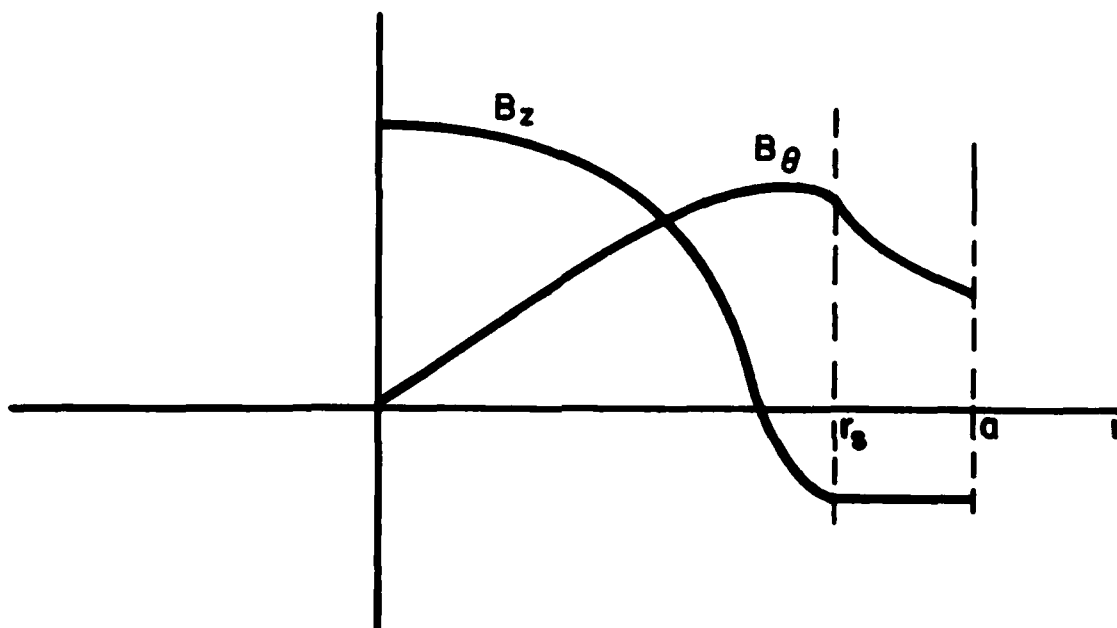


Fig. 2 - The radial profile axial and azimuthal magnetic fields, assuming low plasma pressure on the separatrix

DISTRIBUTION LIST

DOE
P.O. Box 62
Oak Ridge, Tenn. 37830

UC20 Basic List (116 copies)
UC20f (75 copies)
UC20g (62 copies)

NAVAL RESEARCH LABORATORY
Washington, D.C. 20375

Code 4700 (25 copies)
Code 4790 (150 copies)
D. Spicer, Code 4169

DEFENSE TECHNICAL INFORMATION CENTER
Cameron Station, 5010
Duke Street
Alexandria, Va. 22314 (12 copies)

END

DATE
FILMED

9-80

DTIC